
Département Environnements et Sociétés



Modelling the impacts of mechanized sugarcane harvest on the Noodsberg supply chain

*Visit report to University of KwaZulu-Natal
26 April – 4 May 2007*

PROTEA project 05 SHS F20 / SA

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Summary

This visit to the University of KwaZulu-Natal was part of the joint CIRAD – UKZN PROTEA project focused on *Integrated supply chain modelling applied to sugar cane*. It was aimed at supervising the French student who works on the Noodsberg mill area in order to assess the impacts of mechanized harvesting on its supply chain. Two growers harvesting their cane mechanically were interviewed, as well as the mill procurement officer and the Sasri extension officer based in this area. A visit to the mill yard allowed understanding the cane off load systems in place and the various constraints linked to that part of the chain. Three mechanical harvest logistic chains were described based on these interviews and field observations. Discussions were led to conceptualize the logistic chain modelling and to design scenarios based on various mechanized harvest ratios and kind of cane (green vs burnt). These scenarios will be simulated using jointly the ARENA and MAGI software. The harvester/lorries fleet size required to deliver a given amount of cane within a specific LOMS (Length of Milling Season) will be assessed, as well as the scenarios' impact on the sugar production of the mill area.

Key words: sugarcane, supply chain, logistic, supply planning, modelling

Acknowledgements

I would like to thank Louis Lagrange, from the School of Bioresources Engineering & Environmental Hydrology, University of KwaZulu-Natal, and Julien Le Masson for organizing this visit in Pietermaritzburg

After the launching workshop hold in Montpellier from 4 to 6 July 2006¹ and the visit carried out at Pietermaritzburg in September 2006², it was decided to focus the case study planned in the PROTEA project called *Integrated supply chain modelling applied to sugar cane* on the Noodsberg mill area and to investigate impacts of mechanized harvest on its supply chain.

A Master student from AgroParisTech, Julien Le Masson, has been engaged to conduct the field study from April to July 2007, after two weeks spent at Montpellier for literature review and conceptual brainstorming. At the end of this first phase Julien wrote a report where he analyzed potential impacts of mechanized harvest on the mill supply and suggested some possible scenarios that could be simulated both at the logistic level, using a commercial software called ARENA, and at the mill supply area level using MAGI, a software developed by CIRAD (see Appendix 2)

This visit was organized four weeks after his arrival in South Africa in order to (i) look at the activities carried out until now, (ii) meet some stakeholders (miller, growers implementing mechanized harvest) and (iii) discuss the way forward, particularly regarding the modelling and simulation process.

1. Activities carried out in April

During his first month in South Africa Julien was introduced to the Noodsberg stakeholders (mill procurement staff, cane growers), met the SASRI extension officer (Geoff Maher) and tried to collect RV (Recoverable Value) data for every grower in order to evaluate the potentiality of reducing harvest windows according to quality homogeneous sub-areas, as we did in the Sezela mill area in a former study. He also met seven growers to investigate their harvest organization: three harvesting manually, one harvesting mechanically with his own equipment, three contracting mechanical harvesters.

Julien discussed the diversity of cane production within the Noodsberg area with Geoff Maher. Geoff has designed a zoning based on soil, climate and slopes. 11 ecozones have been defined that could potentially be taken into account to differentiate harvest windows per quality-based sub-areas. These scenarios would be valuable assuming these ecozones show significant RV differences at some stage of the harvest season. Then mechanized harvest would provide some flexibility to adjust cane deliveries to alternative harvest windows. But assessing this assumption means getting the growers' individual RV curves in order to calculate the RV curves for every ecozone, and then to test the differences between them over a range of years.

But collecting growers' individual RV data for several successive years has been rather difficult, as the mill does not keep any of these records. 2006 is the only year available at that stage, which is not enough to analyze precisely the geographical and inter-annual RV trends. Indeed, the Sezela study showed the large diversity of RV curves obtained during a short period (2000-2003), due to climatic variations. The monthly RV figures for the mill area that

¹ Bezuidenhout C., Le Gal P.-Y., 2006. *Integrated Supply Chain Modelling and Application in SugarCane. Launching Workshop Report. Montpellier – 4-6 July 2006*. Cirad – University of KwaZulu-Natal, n° 47/06, 13 p.

² Le Gal P.-Y., 2006. *Integrated Supply Chain Modelling and Application in Sugarcane. Visit report to University of KwaZulu-Natal, Protea project 05 SHS F20 / SA*. CIRAD/TERA n°56/06, 12 p.

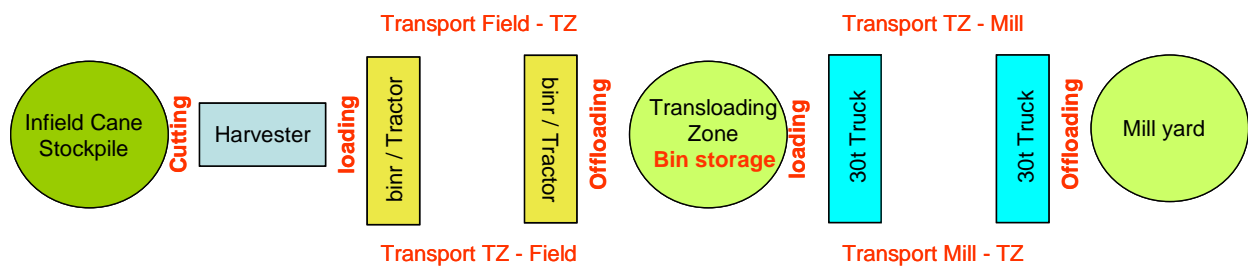
we got during the visit are a first step but they will not be sufficient to simulate properly the planned scenarios (see infra).

2. Logistic chains based on mechanized harvest

Three logistic chains based on mechanized harvest were observed during the visit.

The bin system

This harvest system has been designed by H. Kohne and is used on his farm plus 4 neighbouring contracted farms.

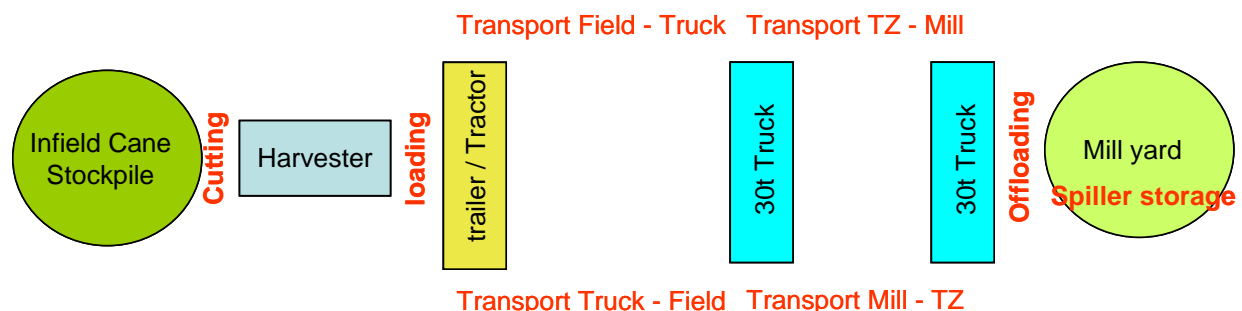


In that case the harvester empties its cane into a bin carried by a trailer. The trailer is hauled by tractor to a transloading zone (TZ) where the bin is stored. Three tractors/trailers work together, while the field-TZ distance does not exceed 2 km. The harvester works at daylight (usually from 9h30 am to 3h30 pm) and 28 bins are available. A 4-bin lorry (30 t payload) loads the cane to the mill, preferably at night (between 4h pm and 8h am) when the queue at the mill entrance is short.

HK estimates his harvester's field capacity between 20 (green cane) and 35 t/h (burnt cane) (maximum: 55 t/h). He harvested a maximum 320 t a day last year. But his usual DRD amounts for 165 t/day.

The direct transport system

This system is used by P. Schroder, who owns 6 harvesters.

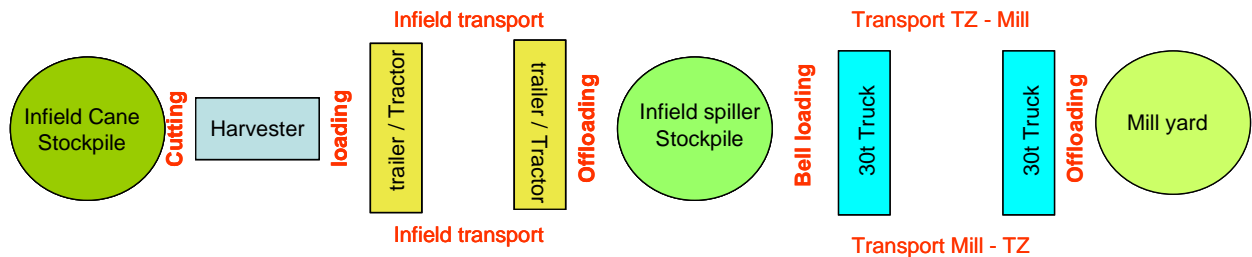


Each harvester works with two tractors/trailers and two 30t trucks. The tractors bring the cane to the trucks at close distance (< 1 km). The cane is directly downloaded from the trailer to the truck. The maximum distance from this loading place to the mill is 37 km. The system work only at daytime, which means that spiller cane would have to be stored at the mill yard assuming the mill runs 24h and the cane is totally harvested that way.

This system can harvest and haul 200 t/day of good cane (harvest: 30 t/h including stops / 50 t/h without) with three deliveries per truck. Green cane reduces this capacity from 15 to 20%, lodged cane from 35%.

The spiller storage system

This system was only seen in a field close to the road (no growers' interview). In that case the spiller cane is stored infield and loaded with a Bell into a 30t truck. This system is used in case of lack of tractors/trailers. But the cane quality drops as it is mixed with mud and soil. This system could theoretically work 24h.

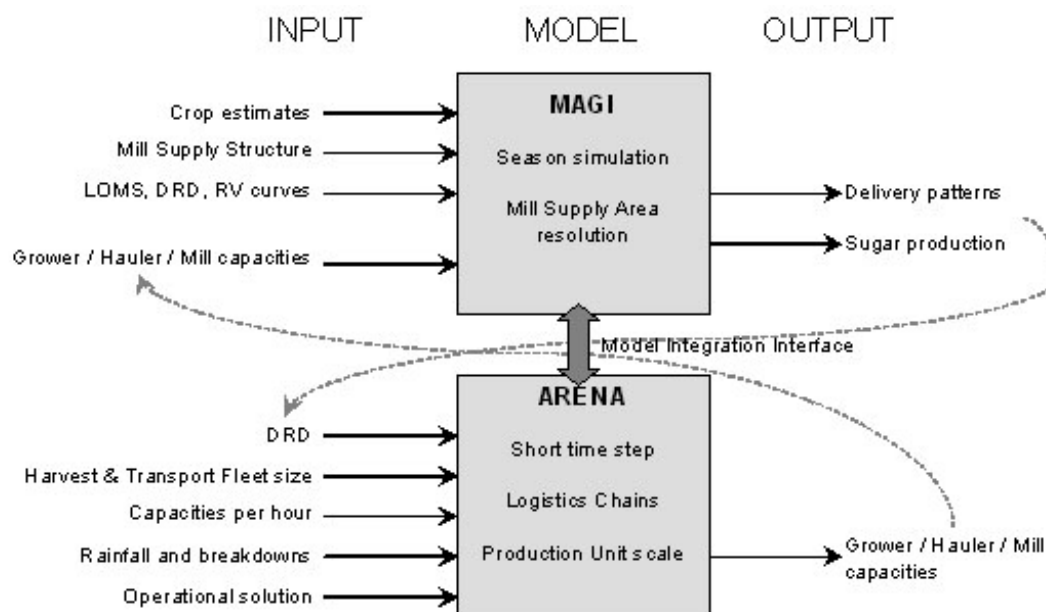


3. Designing scenarios based on mechanized harvest

About 70% out of the Noodsberg mill area could be harvested mechanically. This trend raises three issues:

1. What would be the harvesting and transport capacities necessary to reach this level?
2. How to organize logistics?
3. What would be the impact on mill supply organization (LOMS, DRD) and on the sugar production at the mill area level?

The initial idea was to couple a supply modeling tool such as MAGI[®] with a logistic tool such as ARENA in order to design and simulate scenarios using the following conceptual framework:



A. The first stage consists of splitting the mill into Production Units in order to reduce the diversity and complexity of cane suppliers. Two criteria³ will be considered for their link with the addressed issues:

- (i) the kind of harvest technique (mechanical vs manual) according to the fields' slope;
- (ii) the distance from fields to the mill, which affects the hauling time.

We do not aim to describe precisely the logistics from fields to the mill but to give main trends that could support stakeholders' discussion and learning about this evolution. So we suggest taking a rather small number of PUs defined as follows:

- Fields from different farms will be grouped into PUs; cane quantities will be added and an weighted average %RV curve will be calculated;
- Sloppy parts will be harvested manually (Meyer, 2000 took 20% as a limit)
- Each PU will be organized around one Loading Zone (LZ), except when direct delivery is possible (PU manual at close/medium distance from the mill); the average distance between the fields and LZ will be 1 km.
- Each PU will be allocated a given number of harvest and transport equipment or labour for manual harvesting. There will be no exchange of equipment and labour force between PUs

These assumptions lead to 6 PUs representing the whole mill area:

	Harvest technique	Distance to the mill*
PU1	Mechanized	Close
PU2	“	Medium
PU3	“	Large
PU4	Manual	Close
PU5	“	Medium
PU6	“	Large

* The distance values for each category still need to be estimated.

B. The second stage will consist of defining LOMS according to the total cane tonnage and mill capacity. A good year will be selected as a basis to size the equipment capacity required to harvest and haul it. A rainfall pattern analysis carried out by C. Bezuidenhout shows that rainfall probability decreases between end of March and end of October. Reducing the LOMS by starting latter (April) and finishing earlier (November) would reduce the harvester stops and breakdowns and leave the growers more time for managing their fields after harvest (fertilization and weeding).

C. Once a LOMS has been selected, DRD per PU will be calculated. Each DRD will be split within the week, as days are not equivalent because of the supply interruption on Sundays. The maximum cane tonnage is supplied on Saturdays in order to fulfill the 2-day requirements. This maximum supply will provide the objective to be reached by the harvest/transport logistics chains within the mill area.

³ The RV curve differences between ecozones will not be considered but a brief analysis of the %RV data will be eventually carried out to estimate them.

D. Sugar production may be calculated at that stage using MAGI assuming that a solution will be found to get the DRDs right.

E. The logistic chains will be simulated using ARENA. A new version of the software will be available only in June at the University labs.

. The PU production will be considered as a stockpile decremented by the harvester according to its capacity.

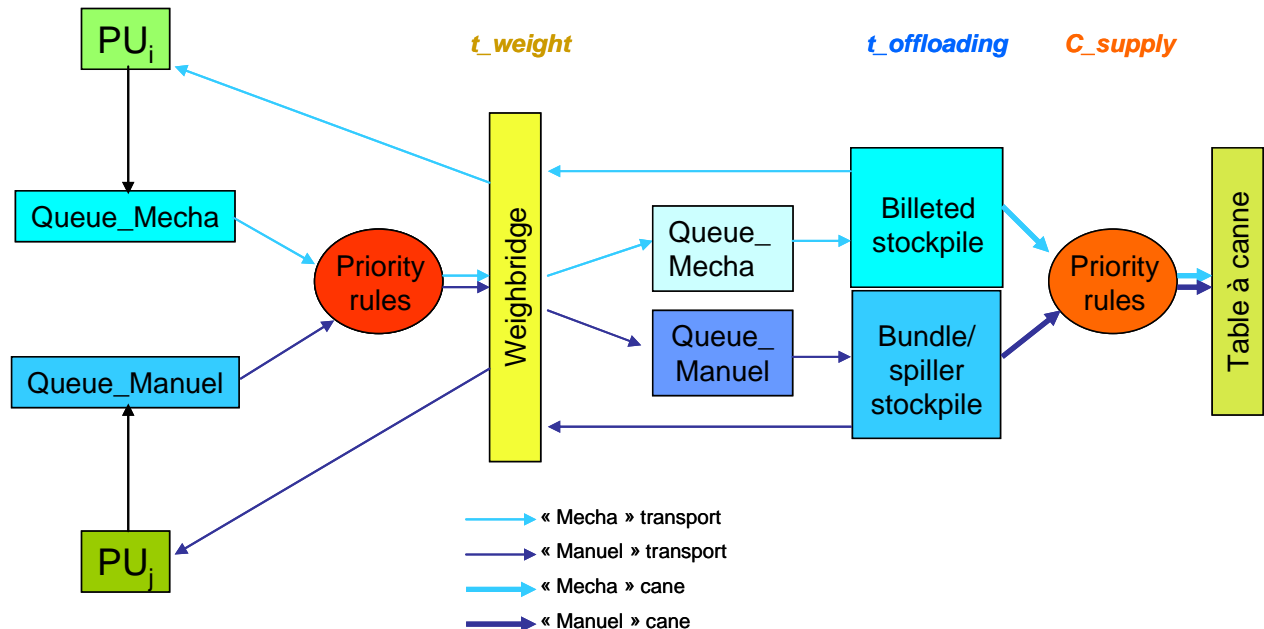
. The logistical chain from the harvester to the LZ will be described (trailers/bins + tractors). Only one kind of chain will be simulated at a time for the 3 mechanized PUs. The same rule could be applied to the manual chains (spiller vs bundle).

. Rules of unloading/loading into trucks at the LZ will be specified:

- wait for a truck to come to unload/load
- store bins at the LZ
- spiller stock pile at the LZ

. All the logistic chains per PU will be simulated simultaneously, in order to simulate the queue at the mill yard and to take into account the delays for a specific truck.

. Modelling the queue within the mill yard has still to be decided according to the following figure.



. A cane stockpile within the mill yard will be simulated in order to take into account this critical parameter in the mill operation, as harvesters work at only at daylight while the mill operates 24h. This stockpile could differentiate billeted and bundle/spiller cane. Each truck will fill one stock compartment and the mill will operate from the 2 of them with a priority rule: 1. billeted; 2. spiller/bundle.

E. These simulations will give an estimation of the equipment and logistic chains necessary to fulfill the DRDs planned above.

F. The simulations will be carried out both for burnt and green mechanized cane, in order to anticipate possible changes in the environmental legislation.

3. Conclusions

The first growers' surveys conducted by the student give good references to calibrate the ARENA model. But the simulation structure still needs to be model and capture using this software. Unknown difficulties could be met during that process.

At the mill level it would be necessary to get individual RV data for more than one year, at least to test the impact of a LOMS reduction on the sugar production.

Some issues could be specifically addressed by the simulations, such as (i) threshold effects because of discrete numbers of equipment and PUs limits to reconsider according to this effect; (ii) harvest at day only vs 24/24 knowing that the mill needs cane to be crushed 24/24.

Issues such as cost-benefit analysis and impact of mechanized harvest on cane quality and cane process efficiency will be tackled by C. Bezuidenhout using CAPCONN.

Appendix 1

Visit scheduling

26 April	Departure from Montpellier
27 April	Arrival at Pietermaritzburg First meeting with Julien Le Masson
28 April	Work session with Julien Le Masson
29 April	Visit of a cane farm in the Noodsberg area (manuel harvest)
30 April	Meeting with Peter Lyne (Sasri)
2 May	Meeting at the Noodsberg mill (J. de Lange, G. Maher) Work session with Julien Le Masson & L. Lagrange
3 May	Meeting with H. Kohne (sugar farm, mechanized harvest) Meeting with P. Schroder (suagr farm, harvest contractor)
4 May	Work session with Julien Le Masson & L. Lagrange Departure from Pietermaritzburg
5 May	Arrival at Montpellier

Appendix 2

Impacts of mechanized harvesting on Noodsberg mill sugarcane supply : an approach based on modelling and simulating organisation scenarios.

**Julien Le Masson
CIRAD 2007-03-15
Montpellier**

INTRODUCTION

South African sugarcane is mainly harvested manually (98% manually harvested – Langton, 2003). Nevertheless, in a relatively close future, mechanized harvesting could increase or even generalize in some of the South African milling areas. Noodsberg Mill Board is willing to get prepared already for a probable increase of mechanization up to 80% within ten years (Preliminary Study, September 2006). Several reasons are point out to justify the use of mechanization : first, the increasing problem of cutters availability due to AIDS and the lack of interest of the young for a difficult agricultural work. Secondly, the unavailability of labour and the social claims have led to a rise of labour cost. Finally, environmental concerns have arisen and burning could be limited or prohibited because of smokes problems and soil deterioration. Green cane manual harvesting would be less competitive than mechanized harvesting.

Changing from manual to mechanized harvesting is not a mere problem of technology and agricultural practices : it involves an adaptation of the whole supply chain and its organisation that enables the routing of cane from the field to the mill. Economical and organisational aspects of such a change bring into play really complex relational systems which force us to reason at a broad scale – the milling area scale – and not only at growers' level.

Higgins et al. (2004) have demonstrated that modelling is an efficient tool to understand and enhance the organisation of a supply chain, giving the possibility to forecast and to test future scenarios. In the present case modelling and simulating supply scenarios are used to evaluate the impacts that a generalization of mechanized harvesting in Noodsberg milling area would have on the mill supply and on the total sugar production at the end of the milling season. Simulating scenarios releases us from experimental constraints linked to the time or the investments that would be necessary if the hypothesis were tested in the field.

The first change that will occur when changing for mechanized harvesting is at a logistic level. Indeed, chopper-harvesters have a cutting capacity significantly higher than that of a manual worker (approximately 50 t/h and 0,5t/h respectively) which implies a totally different organisation of harvest and route transport from the field to the mill. The ARENA Simulation System, already used in South Africa to work on problems such as the reduction of Harvest To Crush Delay (HTCD) (Barnes, 2000) can be used to evaluate the needs in equipment required to ensure the compatibility between harvest, transport and crushing capacities.

On the other hand, if transfer capacities between stakeholders all along the supply chain are not exceeded, mechanization offers a certain flexibility in harvest organisation which allows us to think about alternative supply scenarios that might be more profitable from a sugar

production point of view. MAGI, a model developed by CIRAD for a few years in La Réunion and South Africa, is a tool that can be used to reason on those strategic aspects of the problem.

Beyond technical adaptations due to the incorporation of machines in the system, we are interested in the impact on both sugar production in the milling area and capacities along the supply chain. Actually, logistic and strategic aspects are closely linked since logistics is defined according to strategic objectives which cannot be evaluated without logistic data. That is the reason why the mechanization problem will be solved by coupling ARENA and MAGI.

Modelling at the milling area level the whole milling season cannot take into account the complexity and the uncertainties of the real system. By construction, a logistic model has to be more precise and must describe with details the functioning of the supply chain at a more individual level. Nevertheless, since the logistic model will “feed” the strategic one, an excess of details might be useless or even destructive. Yet, we should know about the particularities of mechanized harvesting, its stakes, its constraints, to know the limits of our simulations and to be able to discuss and to explain the choices of simplified hypothesis that we will have to make. For that purpose, we are giving next the key points of implementing a mechanical harvesting system and the methodology we will use to model Noodsberg mill supply.

ISSUES TO CONSIDER IF MECHANIZED HARVESTING RISES IN NOODSBERG MILLING AREA

Interrogations about mechanized harvesting

One of the main factors that may encourage mechanized harvesting in the future is the environmental impact of burning on global warming and soil erosion. According to Meyer and Fenwick (2003) 80% of sugarcane in South Africa is burnt before harvesting. If legislation passes to limit or prohibit the burning of sugarcane, many growers will choose to harvest mechanically because manual harvesting rates are considerably lower in green cane than in burnt cane resulting in increased costs of harvesting, loading and transporting (Meyer et al., 2005).

Apart from capacity differences, green cane and burnt cane harvesting rely on different agricultural practices that lead to significant differences in terms of yields and cane quality. Since most of the cane in the world is still burnt prior to harvesting, there are few studies that really try to give quantifications about those aspects. Moreover, in most studies, differences between green cane and burnt cane harvesting are usually mixed with the effect of mechanization. It is generally accepted that green cane quality is lower than burnt cane's (higher extraneous matter leads to higher fibre content which reduces the %RV). Mechanization also reduces the quality of the cane (Meyer et al., 2005), mostly because the harvester doesn't reject improper cane and also because soil content tends to be higher.

More detailed information can be found in literature but we can hardly quantify how green cane or mechanized harvesting will impact on tonnages or %RV. Therefore, it may be simpler in a first approximation to consider that yields and cane quality throughout the milling season are similar in green cane and burnt cane systems. This hypothesis would allow us to leave side for a moment the question about green cane, ie: whether both manual and mechanized

harvesting will have to be done with green cane or will cane continue to be burnt prior to manual harvesting? In the case of mechanized harvesting, some studies have been conducted assuming cane is burnt prior to harvesting (AG De Beer, 1977) ; others, like P. Stutterheim (2006) have worked on mechanized harvested green cane. It would be interesting to know what is the current situation in Noodsberg milling area.

Eventually, we could possibly try to take quality differences into account in the models by decreasing arbitrarily the capacity of the mill. This kind of decision would have to be discussed with the mill manager, who could tell us what consequences a rise in soil content or extraneous matter in the cane may have on the milling process.

Agronomic and farm constraints with regard to mechanization must be taken into account individually by growers who plan to mechanize and have to adapt their agricultural practices to this change. Yet, it would be an error for us to go for details and an average situation must be described. Nevertheless, important issues such as the size of the farm, topography, soil characteristics (drainage capacity after rains) and microclimate should be considered when determining coarsely the zones or the Production Units (UP are a basic item of MAGI) corresponding to mechanized harvesting.

Logistics of mechanization (ARENA simulations)

Mechanization shortens harvest time. Previous works have established some references concerning the increase in harvesting capacities (AG De Beer, 1977 ; P. Stutterheim, 2006). Strategically, it has been demonstrated in the Sezela milling area (Le Gal et al., 2004) that a shorter Length Of Milling Season (LOMS) centred on the high %RV period could increase total production of sugar. One of the barriers encountered at that time was the limit of harvesting capacities. Mechanizing the harvest in Noodsberg milling area could be an option to increase sugar production.

Obviously, an increase in harvesting capacities would be useless if transport capacities or crushing capacities were limiting factors. Using the ARENA Simulation System will help us with the testing of different organisation scenarios of the supply chain, determining the number of chopper-harvesters and the total fleet needed to convey the cane from mechanized farms to the mill. Those organisation scenarios should be built according to the existing situations and based on interviews of farmers and Noodsberg mill's supply managers. The method used by AJ Barnes et al. in 1998 could serve as an example. Estimations of delays throughout the whole chain should be made, to determine the capacities of each of the stakeholders, depending on the system studied (manual harvesting, mechanized harvesting, ...etc). Once logistic chains are modelled, a total capacity can be used to account for the equivalent of a Production Unit capacity (which makes the relation between ARENA and MAGI).

Delays will be used as a selective factor to compare scenarios. Since cane deterioration is higher in chopper-harvested cane than in burnt manually harvested cane, the Harvest To Crush Delay (HTCD) must be lower than 20 to 24 hours (AG De Beer, 1999). We can then imagine that a specific organisation of the supply chain has to be planned for mechanized farms, facilitating for example direct delivery of the cane from the field to the mill. Apparently, most of the growers are already delivering the cane directly to the mill, which causes some queuing problems with significant delays at the mill entrance. If mechanized harvesting increases, with every farm delivering the cane from the field directly into the mill

yard, queuing and storage problems will be exacerbated. The logistic chain simulations will be useful to test other scenarios such as: developing transport with high payload or/and passing through transloading areas that could gather cane coming from different fields before delivering it to the mill. This kind of transport system is likely to be more practical for non-mechanized harvesting because HTCD will certainly be higher. Taking HTCD as a constraint, it might be necessary to work specifically on queuing problems. We will have to decide whether we must detail weekly organisation (as it was done by Barnes et al., 2000) or no : does it make any sense to do so if we try to model the logistic chain for each PU as a whole ?

This study will not contain any economical analysis of alternative scenarios designed to deal with mechanization. However, it is important to think of realistic scenarios and from an economic point of view, it means we should try to determine the minimum number of machines (chopper-harvesters and transport vehicles) required to haul a given quantity of cane from the field to the mill. The number of chopper-harvesters will depend on mechanization ratio, LOMS and cane volumes, and will vary with threshold effects.

If we have enough time to get into details, we could try to model variations in harvesting efficiency, depending on climatic events, for example. Rain may compromise the use of chopper-harvesters and there-by decrease harvesting capacities of the machine. Just as it is done in MAGI for the mill, we must take into account break downs and maintenance time for the machine utilization in the field. LOMS may have an impact on the capacities too: if the LOMS is longer, fewer machines will be required and may work at a lower capacity. But shortening the LOMS could impact positively on the total sugar production and decrease the risk for harvesters to operate during rainy periods at the end of the season.

Finally, we might have to relativize the aptitude of chopper-harvesters to work in a continuous way in the model. If we model logistic chains corresponding to each PU, we may be tempted to reason the PU zone as one single farm and describe an average situation for the logistic organisation. This reasoning has its limits and a detailed reflexion about how chopper-harvesters will be used might be necessary. Will they harvest a whole farm in one row and then work on another farm the following day or will they harvest part of each farm at different moments of the season? The first option seems quite difficult to establish because it brings a host of social, economic, technical and agronomic problems (how can unfair payment can be avoided? how will the farmer manage labour bottlenecks? What are the risks to concentrate the whole crop cycle on a short period? Aren't diseases and pests going to be a greater problem? Are some of the many questions that would have to be answered...). The second option implies that supply chain modelling should integrate delays due to the displacement of chopper-harvesters.

As we can see through this quick look at logistic modelling, we will have to make significant choices when modelling the supply chain, to be as precise as we can be without passing over the limit of significativity and interest for the strategic simulations.

Mechanization & changes in the organisation of the milling season (MAGI simulations)

The objective of a MAGI simulation is to compare the results of different supply scenarios (alternative ones and the current one) according to sugar production and capacity constraints throughout the chain. Harvest mechanization offers a certain flexibility in terms of capacity and allowance of the resources (it is easier to transfer machines from one farm to the other than workers) we could take profit of to elaborate new supply scenarios.

Discussion about supply scenarios

Imagining what possible scenarios could be tested in the future may be useful to guide ourselves and identify the key problems linked to the mechanization of the harvest. Without using MAGI, we can simply reason on DRDs (Daily Rateably Delivery), LOMS (Length Of Milling Season), Milling capacities and PUs (Production Units) and try to determine what are the main problems we face with simple scenarios.

Definition of Production Units :

Production Units are individual elements treated as homogeneous from a capacity and cane quality point of view as well as for the rules that the mill applies to them for planning and operating delivery (Le Gal et al., 2006).

One of the important aspects of the study for the MAGI simulation is the definition of the Production Units. As it has been done in previous studies at the Sezela Mill (Le Gal et al., 2002 to 2005) we can plan to divide Noodsberg Mill area into different eco-zones or climatic zones. The preliminary study carried out in September 2006 concluded that the total production area could be split into 6 homogeneous climatic zones (HCZs). A first step should be to verify that %RV curves are different from one zone to the other, which would give us the opportunity to establish different harvest windows for each zone to stick to the pick of %RV during the milling season.

Apart from the climatic zones, PUs may differ according to their harvesting and/or transport capacities that make the way the mill manages them different. Without entering into complicated considerations yet, we can divide the growers into 3 different groups: manual burnt cane, mechanized (green or burnt ?) cane and small scale growers. It was noted in the preliminary study of September 2006 that Noodsberg crushes cane provided by the closely located Union Co-op Dalton Mill. That cane can be treated as another PU named 'diversion'. In this study, we can imagine that no Intermediary Operator as they are defined in MAGI will be needed. The capacity of each PU could be, as we already mentioned, the result of the global (harvest + transport) capacity of the corresponding logistic chain modelled with ARENA.

Noodsberg mill crushed an average of 1,443,000 tons per year from 1999 to 2005. The mill crushing capacity is approximately 300 t/h and the optimal LOMS is 37 weeks long. Assuming the mill operates 159 hours per week, its average crushing capacity fluctuates around 1,750,000 tons per milling season. Apparently the margins are sufficient to give some flexibility to the system. Nevertheless, it seems that poor cane quality makes the mill backend limiting. It would be interesting to understand the reason why the mill backend is under capacity. We might want to link this problem to quality indicators used in MAGI: brix, fibre and non-sucrose. It would give us the opportunity to get a more precise simulation and eventually to work on different hypothesis for green cane or burnt cane harvesting. At first, we might want to reason on crushing capacities to simplify the problem.

Reference scenario : current situation

Currently, very few growers are mechanically harvesting in Noodsberg milling area. Assuming they represent a negligible part of the production at the moment, we can roughly

trace the DRD for the current situation (Figure 1). The distribution of the DRDs between all three PUs has been arbitrarily chosen but total DRDs cannot exceed the mill crushing capacity (=100%). As it is usually the case in South Africa, DRD is uniform during the season. The harvest window (defined by the LOMS and the start/end date) is the same for each PU.

Scenario 1 : same as current situation except for mechanisation

In this first alternative scenario, a group of growers would go for a mechanized harvesting. The first question that comes to mind is: who are these growers? We can assume for the moment that they are large scale growers. If we do not specify anything else about this change, we can just differentiate mechanized and non-mechanized large scale growers on the precedent graph and transfer part of the DRDs to the mechanized growers (Figure 2). This scenario would resume itself to a mere problem of logistics that we would have to discuss using ARENA.

Scenario 2 : harvest window centred around %RV maximum values

We may want to benefit from the higher harvesting capacity of a chopper-harvester by reducing the LOMS and centring it on the pick of the quality curve. Assuming the mill is functioning at its maximum capacity today (but we need to validate this assumption), this could be achieved only if the mill capacity were increased. Two possible solutions to solve this problem:

- an investment of the mill to build up a new line of production or to solve the backend problem.
- not to crush the cane coming from the Union Co-op Dalton mill, thus increasing the capacity to crush more cane coming from the milling area (Figure 3).

DRDs are higher than in scenario 1 because diversion DRD has been redistributed amongst the other PUs. MAGI will be used to manage accurately this kind of change and to calculate the eventual gains in sugar tonnage at the end of the milling season.

Scenario 3 : mechanized harvest window centred on %RV pick – diversion completes

A thorough study of scenario 2 would probably point out a problem of over capacity for SSG and manual harvesting. This third scenario takes this remark into consideration and aims at reducing the mechanized harvest window without changing the current harvest windows of SSG and manual harvesting.

The middle of the milling season is limiting the whole organization of the supply because total DRDs must be inferior to the mill crushing capacity at any moment. Therefore, at the beginning and at the end of the milling season, when mechanized harvested cane is not delivered to the mill, its crushing capacity is not fulfilled. To compensate the lack of cane from the milling area during these periods, we could imagine that cane provided by Union Co-op Dalton Mill is crushed by Noodsberg (Figure 4). In this scenario, gains in sugar tonnage would rely only on the centring of mechanically harvested cane upon the quality curve. On a practical point of view, crushing cane provided by Dalton Mill only at the beginning and at the end of the milling season seems quite difficult to do because of contracts negotiated between both mills.

These simple and coarse examples of possible interpretations of the problem only intend to show the complexity of the question of harvest mechanization. They give a few orientations that will have to be thoroughly studied. Beside, the links between MAGI and ARENA simulations must be more accurately defined, certainly by studying every PU capacity.

MODELLING SUPPLY CHAIN : METHODOLOGY

The difficulty of modelling the supply chain to study the impact of mechanized harvesting on Noodsberg mill sugarcane supply lies in the coupling of two models that work on different levels : logistics and strategy.

Another difficulty lies in the complexity of the system studied. On such a broad subject, every question leads to another. Thus, the risk is to get dispersed trying to solve every problem, which is impossible on a 6 months period and difficult to model. Moreover, many questions that are discussed are valid at a restrict scale (both in time and space) but not for the milling area or the whole milling season.

We must then establish some priorities and decide of a certain level of study beyond which precision of the information is more a harm to the clearness of the results than a real improvement. It is important to set up a working schedule so that we know how to organize our work:

1) Delimiting homogeneous zones = pedo-climatic zones at first

We can count on existing works :

- Carel Bezuidenhout has divided Noodsberg milling area into 6 Homogeneous Climatic Zones (HCZs): 2 arid irrigated valleys, 2 mistbelt escarp regions and 2 plateau areas.
- Noodsberg mill has divided its suppliers into 11 “eco-zones”. We should rapidly determine what are these zones corresponding to. They seem to be based on administrative divisions and not on ecological aspects.

We can think of locating and delimiting the zones geographically so as to define a centre of gravity for each zone. Every barycentre will represent the whole zone and the distance between that point and the mill will be used as a parameter for logistics simulation.

2) Determining whether it exists quality differences between these zones or not

Dividing the milling area into climatic zones is useful only if significant quality differences are detectable from one zone to the other. In that case, we could imagine different supply scenarios for each zone (different ‘harvest windows’, different respective LOMS, ...) as it has been tested on Sezela mill (Guilleman et al., 2002).

The fact that Carel Bezuidenhout’s sub-division of the region were formerly determined to model cane production responses to different climatic conditions encourages us to think that effectively there are quality differences between these zones. Still, it has to be verified by tracing quality curves (%RV) for each zone and for several years. We shall have access to the mill data base to get the weekly information for each farm.

3) Defining PUs according to established zones and supply chain particularities

Production Units (PUs) must be defined according to the climatic zone they are included in and their technological (mechanized harvesting, for instance) or delivering (SSG, diversion) particularities. In order to keep the number of PUs reasonable, we will have to think of a simple division that makes sense. For instance, we might want to consider regrouping into a single PU mechanized farms and arid irrigated valleys, especially if mechanization rates are high. The PUs are characterized by their tonnage, their quality curve and the harvest window attributed in each scenario. These characteristics are used to calculate respective DRDs that will be major inputs for both logistic and strategic models.

4) Modelling logistic chains of each PU (ARENA)

The following stage consists of modelling logistic chains of each PU using ARENA Simulation System. The know-how and experience of UKZN team will be appreciated when using the model. Conceptualisation of logistic chains and parameters setting of the model must be based on the knowledge of the actual situation and on interviews conducted with people concerned by the different stages of the supply chain: farmers, haulers, mill. Noodsberg Cane Supply Manager (Julius De Lange) and Mill Manager (Mike Crossman) will be privileged interlocutors.

In comparison with former or current studies about logistics, it may be necessary to have a different approach, more aggregated in the way that ARENA must be a tool basically used to estimate capacities. The optimisation of HTCD and other precise questions about transport are eventually going too far into details compared to the time we have and the utilization of the model that we plan (coupling ARENA outputs with MAGI, which is not a logistic model).

5) Modelling harvest organisation during the milling season (MAGI)

Once logistic chains properly described and harvest, transport and crushing capacities precisely determined, we will be able to study different aspects of harvest organisation during the milling season that we have rapidly presented above.

6) Discuss feasibility and profitability (sugar tonnage) of alternative scenarios

The alternative scenarios simulated with ARENA and MAGI will be discussed with the Mill Group Board on the basis of their feasibility (at what cost?) and their economic interest (total sugar production at the end of the milling season).

A few interrogations

- It would be interesting to know how are the current mechanized harvesting farms proceeding. Do they burn cane prior to harvesting? How is organised the delivery of the cane (direct transport form the field to the mill? What kind of transport vehicles are used, ...) ? Is the quality of the cane they deliver different? Are there different techniques used and does it make any difference ?

- It is important to know what are the main motivations for the Mill Group Board to expand mechanized harvesting. It could have an influence upon the hypothesis we make about whether the cane would be burnt or not prior to harvesting.
- Despite the fact that we cannot, as we underlined, enter into too much details, we could try to evaluate the main consequences of mechanization from the grower point of view. It is important to have this in mind to avoid any unrealistic scenario.
- How detailed / precise should the logistic simulation be ?
 - If different supply scenarios can be studied (depending on cane quality differences between homogeneous zones, flexibility concerning the mill capacity), logistic simulations should be focused on determining capacities throughout the chain.
 - If there is no much flexibility to consider alternative scenarios, a deepen study of logistics should be made.
 - Should differences between green cane and burnt cane be modelled? On a day-to-day basis, differences could be significant. What about differences on a broader scale?
 -
- Time should be spent with Noodsberg Mill Manager to discuss the ways to increase mill capacity. Why are they crushing cane from Union Co-op Dalton Mill and diverting part of their cane to Elton Mill?
- Should we differentiate two logistic chains in the logistic model if the corresponding PUs will be treated as a unique one in MAGI ?
- Can ARENA model the milling process? (Apparently it models only the transport of the cane from the field to the mill gate and the mill **yard** organisation). It would be interesting to see how crushing capacities of the mill vary with the type of cane delivered and its quality (trash, extraneous matter, %RV). Indeed mill capacity will have a great influence on logistics and organisation possibilities.

Figure 1 : Reference scenario, current situation.

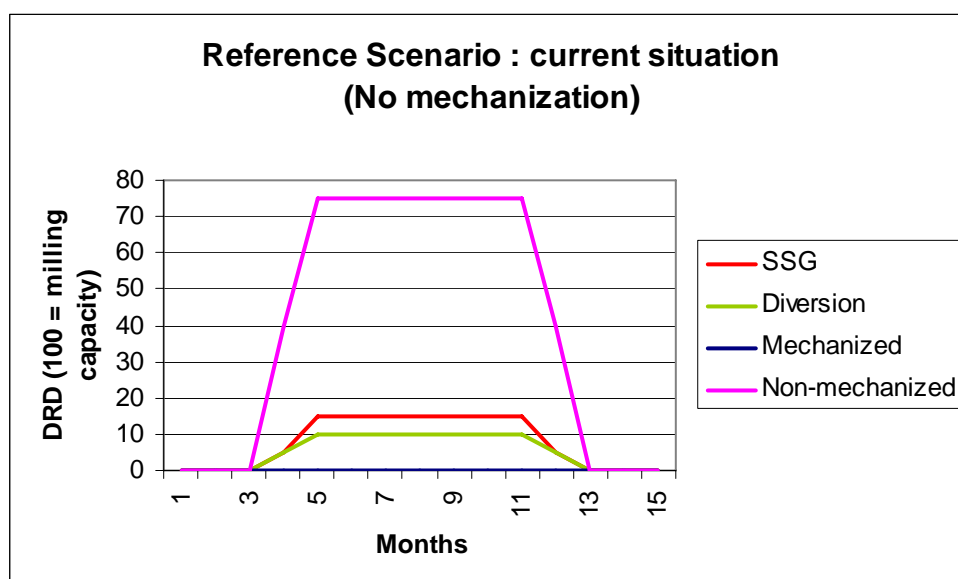


Figure 2 : Scenario 1, mechanization

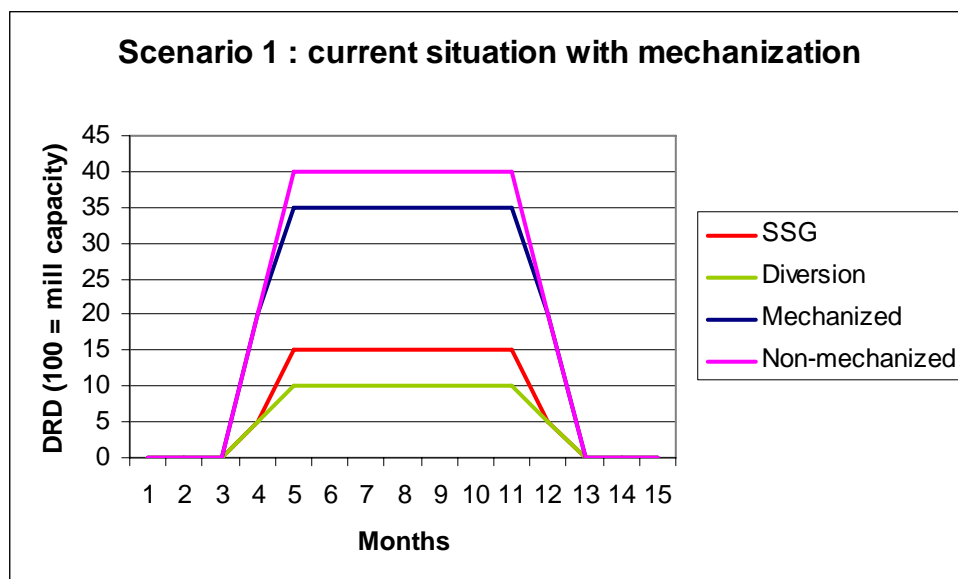


Figure 3 : Scenario 2, reducing LOMS

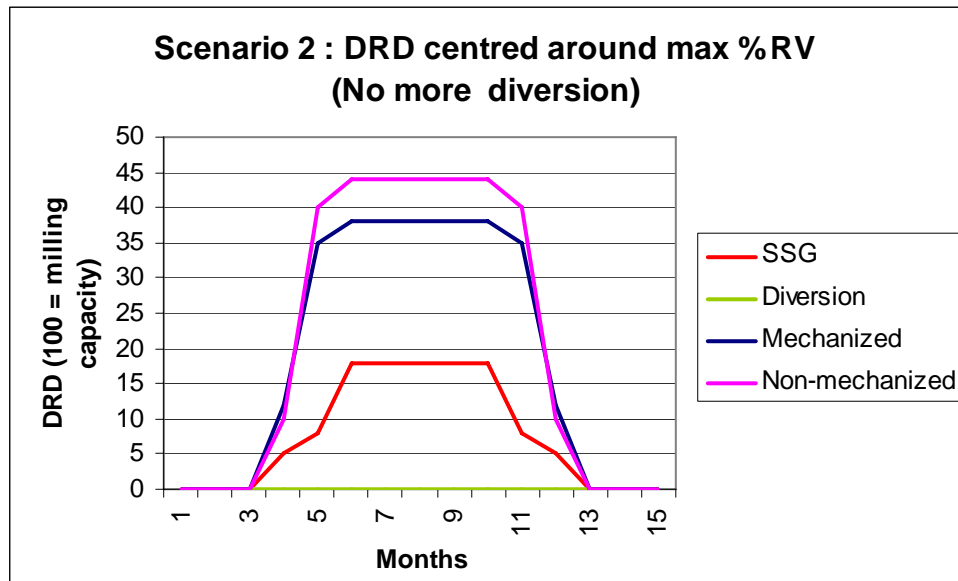


Figure 4 : Scenario 3, a reduced harvest window for mechanized harvesting

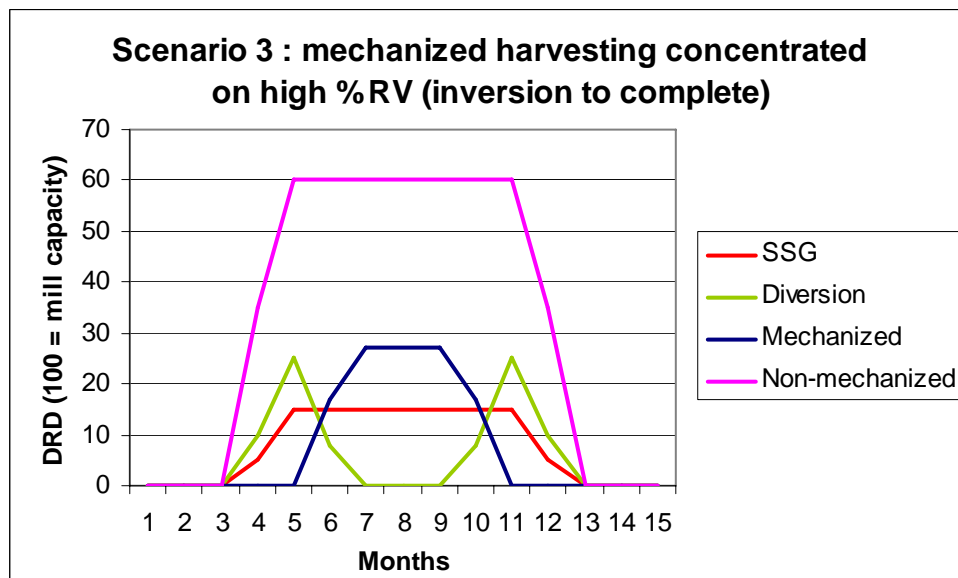
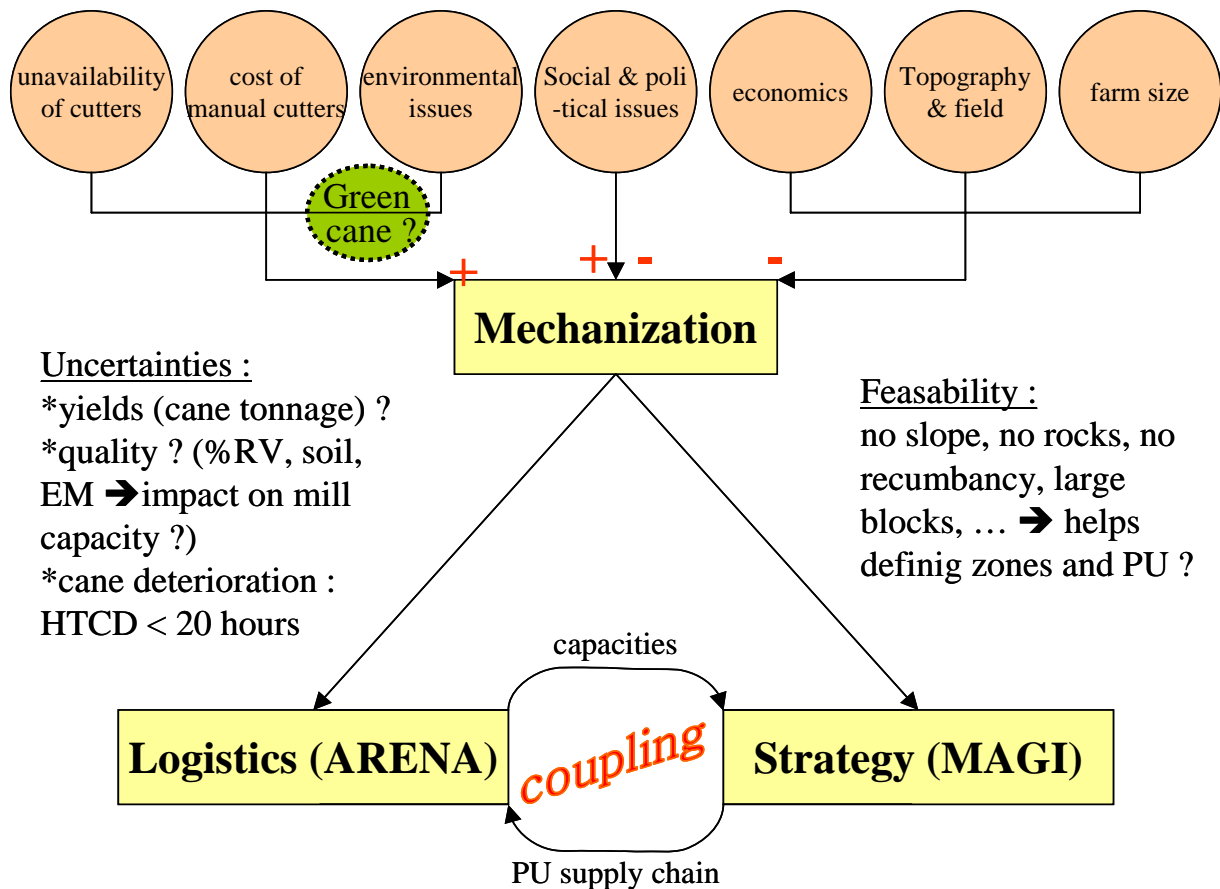


Diagram : modelling the impacts of mechanized harvesting on sugar cane supply chain.



Capacities estimations :

- harvest capacities (manual / mecha.)
- corresponding transport cap. needed
- minimum mill crushing capacity...
- # of machines needed
- simulation of each supply chain

Organising milling season :

- defining significant PU = coupling eco-zone + mechanized (2types ?) + manual harvesting + SSG + ???
- different 'harvest windows' ?
- more flexibility with mecha. harvest?
- sufficient mill crushing capacity ?
- impacts on average %RV ? tonnage ?

Modelling & simulating organization scenarios

- Simplifications** : general hypothesis must take into account more specific possible variations
- Hypothesis** : mechanized harvesting = 25-50-75% ? Possibility to increase mill capacity ?